Learning from Computer Games

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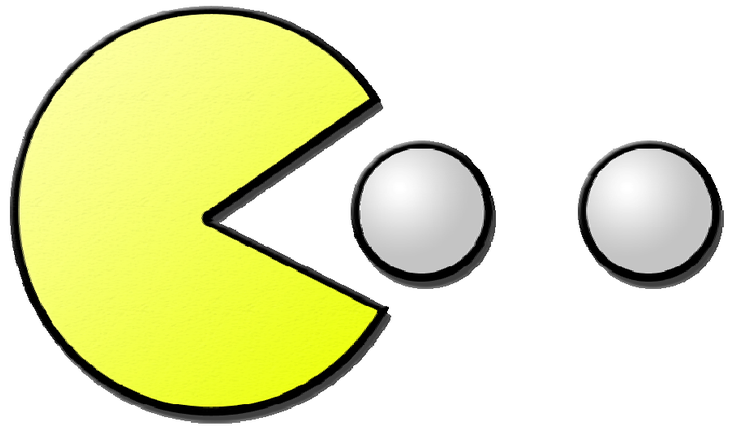

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FOI-R--2396--SE Methodology report **Command and Control Systems**
ISSN 1650-1942 December 2007

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Titel	Att lära sig från datorspel
Title	Learning from Computer Games
Rapportnr/Report no	FOI-R--2396--SE
Rapporttyp Report Type	Metodrapport Methodology report
Sidor/Pages	22 p
Månad/Month	December
Utgivningsår/Year	2007
ISSN	ISSN 1650-1942
Kund/Customer	FM
Forskningsområde Programme area	2. Operationsanalys, modellering och simulering 2. Operational Research, Modelling and Simulation
Delområde Subcategory	21 Modellering och simulering 21 Modelling and Simulation
Projektnr/Project no	E7151
Godkänd av/Approved by	Staffan Nählinder

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Sammanfattning

Kommersiella datorspel tillhandahåller en utmärkt miljö för aktivt lärande och problemlösning. Kommersiella datorspel har också visat sig vara mycket användbara för militär träning och planering. Denna rapport ger flera exempel från detta område. Till exempel diskuteras direkt användning av datorspel för militär träning, anpassning av kommersiella spel för ett specifikt syfte genom att till exempel ändra i spelets terräng och miljö. ”Serious Games” är spel som är nyttobaserade snarare än underhållningsbaserade. Serious Games, spelmotorer för Serious Games och simulatorer som är speciellt framtagna för militär träning diskuteras också i rapporten.

Inlärningsfaktorer, som lärande, överföring av lärande (från spel till verklighet) och återuppspelning av tränade scenarier berörs i rapporten. Fidelity diskuteras också, det vill säga i vilken grad spel eller simulatorer överensstämmer med den verkliga miljön de försöker efterlikna. För utbildning och träning är kognitiv fidelity troligtvis mycket mer kritisk än simulatorns fidelity. I det perspektivet, presenteras arbete inom kognitiv modellering och datorbaserad representation av mänskligt beteende med syftet att skapa realistiska spel och simulatorer med människoliknande beteenden hos fiender och medspelare (Computer Generated Forces, CGF:er).

Nyckelord: Lärande, Datorspel, Serious Games

Summary

Commercial computer games provide an excellent environment for active, critical learning, and include several characteristics of problem solving. Commercial computer games have also shown widespread application for military training and planning. This report presents several examples from this field. The examples include straightforward use of commercial computer games for military training, and adaptation of commercial computer games to the purpose intended, e.g. by change of game environment. Serious games and simulations explicitly constructed and designed for military training are also discussed. Examples of serious games as well as game engines used for serious games in the military context are also given.

Educational aspects such as learning, transfer of learning, and after action reviews are briefly touched upon. Fidelity is also discussed, i.e., the degree of similarity between a game or simulation and the equipment that is being simulated. However, for educational or training purposes the cognitive realism is probably a far more critical factor than fidelity. In this respect, work on cognitive modeling and human behavior representation is presented, with the purpose creating realistic games and simulations with human-like enemies and team-mates (Computer Generated Forces, CGF).

Keywords: Learning, Computer Games, Serious Games

Contents

1 Introduction

Computer games have been shown to grab people's attention and keep their attention for quite long periods of time. People are motivated to improve their performance in games and invest time to improve their skills and knowledge, even though the task is often extremely abstract and artificial. Games are effective teaching and training devices for students of all ages and in many situations. Games are highly motivating, and they efficiently communicate their concepts and purpose. Games give representations of the subject or problem being studied and allow the players to assume roles, face problems, formulate strategies, make decisions, and get instant feedback on the consequences of their actions. And all this is done without physically having to leave the living room (Michael & Chen, 2006)

Many movies and TV-series also have a remarkable way of getting the viewers attention quickly and keeping it for hours. Games have the advantage of allowing the user to immediately use his or her newly acquired skills and to further improve his or her performance by constantly giving feedback and rewards for correct behavior.

In this light, it is easy to understand the idea to use the same type of games to teach people skills and facts to gain knowledge that is useful in the real world. Serious Games as a concept has been around for several years as a general idea to make games with this purpose. Even though there is no clear definition of Serious Games, a Serious Game is made with the purpose to teach rather than to entertain. Several initiatives have failed simply because they have been too serious while having too little "game" feeling and therefore quickly have become boring and uninteresting for the players. It is important to balance the seriousness with the game feeling and a useful pedagogical approach so the game becomes educational *and* fun.

In this report, many examples are given from using games and serious games in various settings, even though the report especially focuses on military settings.

2 Computer games – application and utility

The worldwide market for computer games and interactive entertainment hardware and software is expected to grow from £11.7 billion (~$24 billion) in 2002 to £17 billion (~$35 billion) 2007. Thus, game development is one of the fastest growing and most economically successful kinds of software (Zaphiris & Ang, 2007). The game industry is considered "growing up", not only in terms of subject matter, but also they way games are designed, developed, distributed and played (Michael & Chen, 2006). Games are now a part of mass culture.

2.1 Educational aspects

Computer games include many characteristics of problem solving, e.g. unknown outcome, multiple paths to the goal, construction of a problem context, and collaboration in multi-player games. Thus, game-based learning is in several respects similar to problem-based learning, where specific problem scenarios are often placed within a play framework (Ebner & Holzinger, 2007).

Computer games provide an environment for active, critical learning. Computer games also open up possibilities for simultaneous learning on multiple levels, where players may learn from contextual information embedded in the dynamics of the game, the organic process generated by the game, and through the risks, benefits, costs, outcomes a and rewards of alternative strategies that result from decision making (Raybourn, Mendini & Heneghan, 2005).

In commercial computer games, the players are generally awarded for speed. However, in educational games learning may be best promoted by elaborated, hence more time-consuming styles of interaction.

For enhanced learning, after action review of the game is a central aspect. This provides important cognitive and metacognitive functions that are imperative to solidifying the learning experience (Raybourne, 2007). For instance, the after action reviews is one of the key components of the educational concept in the Swedish VR-based research flight simulator ACES (Air Combat Evaluation System). In ACES a set of pedagogical tools provides enhanced feedback during the after action review, e.g. time tools (slow/quick flight, freezing, cheat roll, mistake correction, space tools (exchanged position), different camera modes (instructor view, God's eye view of entire scene), visual enhancements, and traces and altitude markers (Nählinder, 2004).

ELECTRA is a European interdisciplinary research effort to utilize the advantages of computer games for educational purposes, and addresses and eliminates the disadvantages of traditional game-based learning. One central issue is adaptability, which means that the game must adapt to the learner's knowledge, skills, abilities and motivation. Thus, presenting objects suitable for each individual's learning progress, that is neither too easy, nor too difficult. The cognitive framework underlying adaptivity in *ELEKTRA* is the Competence-based Knowledge Space Theory (CbKST). It provides a set-theoretic framework for the organization of domain knowledge and for representing the knowledge in individuals. The assumption is prerequisite relations between objects. For instance, if the knowledge of object *a* is necessary for the knowledge of object *b*, then the mastering of object *b* assumes the knowledge of object *a* (Kickmeier-Rust et al., 2007).

2.2 Commercial computer games in military training.

Commercial computer games have shown widespread application for military training and planning. Here, some examples of their use in the military domain are given. An early version of Doom II was used to train marines at the Marine Corps Modeling and Simulation Management Office. Tom Clany's Rainbow Six was on temporary hold following September 11th,2001, but was later modified using maps and scenarios requested by the US army to train troops to fight terrorists in urban terrain. With the purpose of adapting game engines for evaluation of collective team working, procedures and communication, QinetiQ and Maverick Developments has developed DIVE (Dismounted Infantry Virtual Environment). The first version was based on the original Half-Life engine, and has been upgraded with the Half-Life 2 software kit. (Stone, 2005).

The third-person perspective computer game Neverwinter Nights has been used for a study of training of military teamwork skills. The experiment was performed in the US Army Gorman's Gambit project, with the purpose of achieving effective military teamwork training with massive multiplayer games. Gorman's Gambit is a part of a larger DARPA funded government program DARWARS concerned with facilitating effective experiential training (Weil, Hussain, Brunyé, Sidman & Spahr, 2005).

Massively multi-player game (MMP) is a term for games that can accommodate large amounts of users simultaneously. A typical MMP game can have thousands of simultaneous users at the same time. However, usually only 2,000 to 3,000 players can be in the same part of the game environment at the same time. To evade this limitation, the gaming industry separates the mass amounts of players in parallel worlds. Another characteristic of MMP games is that they run on standard PCs with typical hardware and tolerate internet connections with limited bandwidth (Mayo, Singer & Kusumoto, 2006). Several MMP games can be used for military training e.g. tactics and cooperation.

Several commercial computer games have been used for training of co-ordination and command and control, of both military and civilian operations, and for studies of communication and common situational awareness and expertise (e.g., Hasewinkel & Lindoff, 2002). A number of commercial computer games can be modified, for instance by change of game world which may be used to provide a specific study with the proper context. Even commercial computer games that cannot be modified can be of use in some studies. Thus, the use of commercial computer games for training and research can provide a viable alternative to expensive development of specific simulations.

Commercial computer games often offer highly detailed and realistic environments. However, there is often a lack of realism in the behavior of the implemented software agents. When computer games are used for military training this problem is pronounced. The agents' incapacities of hiding often destroy the immersiveness of the simulation, and thus the emotional involvement of the participants. For instance, agents may not duck behind a nearby rock, tree, or vehicle to escape hostile fire, or if they reach cover, they may not conceal their entire body from view. According to Darken (2004), the main reason is not that the agents are doing the wrong things with the information they have, but that they are provided with too little information. That is, the agents are not perceptive enough. Darken means that the major reason for this is that algorithms for generating and exploiting information to the agents have not been available. As an attempt to solve this problem, three alternative visibility models and corresponding concealment algorithms are presented and discussed by Darken (2004). One of them, the sensor grid concealment algorithm, was implemented on top of America's Army version 1.6. Informal testing has

showed successful hiding in environments with various types of objects including as rocks, trees, vehicles, and buildings (Darken, 2004).

Research with the aim of providing computer agents with a more realistic behavior is also performed at the Swedish Defence Research Agency (FOI). The of Department Decision Support Systems in cooperation with the Department of Man System Interaction (MSI) have performed a series of studies of modeling and simulation, and of cognitive modeling and human behavior representation. Cognitive modeling refers to activities with the purpose of developing simulation models of human behavior, mental activity, and/or perception. That is, the aim of cognitive modeling is to build models of human mental mechanisms, and models that behave human-like. A starting point has been the military need of models of human behavior for computer generated forces (CGF) (Lundin, Castor, Holmström-Strehlenert, Alfredson & Lundin, 2005; Wallin, Nilsson, Lundin & Castor, 2005). Within the field of cognitive modeling a number of modeling architectures have been developed, which are described in for example Pew & Mavor (1998) or Castor, Wallin, Nilsson & Moradi (2002). The developments in the research field of cognitive modeling are highly applicable to the development of, for training purposes more useful agents in computer games. The Department of Man System Interaction participates in a NATO research group on human behavior representation. The work of the research group will result in a soon forthcoming NATO RTO report that will provide a recent high-level review of the field of human behavior representation (NATO RTO HFM128, forthcoming 2008).

Examples of activities performed by FOI in the field of cognitive modeling are further development of library functions, development of methods for measurements of human movement patterns, accompanied by modeling and visualization, definition of demands for collection of other human data (e.g. psychophysiological, behavioral, cognitive) for use in CGF modeling of dismounted soldiers (Wallin et al., 2005). The work has resulted in a first issue of guidelines for development and use of models of human-like behavior for the support of research concerning CGF implementation and development (Wallin, Lundin, Nilsson & Hasewinkel, 2003; Nilsson, Allberg, Lundin, Wallin & Castor, 2004).

2.3 Serious games and simulations

Originally, serious games were mainly commercial entertainment games with serious elements included, e.g. *Civilization* and *SimCity.* Later on serious games have been developed specifically for non-entertainment purposes (Zaphiris & Ang, 2007). Raybourn (2007) defines a serious game as the use of interactive technologies for training and education in private, public, government, and military sectors. Michael & Chen (2006) say that the goal of a serious game is to educate, train and inform. For instance for adaptive training systems, which Raybourn describes as serious game-based systems with the goal to engender communication opportunities for players to learn about their strengths and weaknesses, receive real-time in-game assessment feedback on their performance, and share diverse solutions and strategies during, between, and after game play in order to update and adapt their understanding.

According to van Erp and Werkhoven (2007) serious games are intended to provide an engaging and self reinforcing context to motivate and educate players. Since serious games are meant to facilitate creative and educational processes, they should optimally exploit the cognitive resources of the participants. In line with this, van Erp and Werkhoven propose a Brain Machine Interface (BMI) that allows direct communication between the user's brain and the system. For serious games, non-invasive EEG measurements with the purpose of finding neural correlates are of special interest. For example, extracting the users navigational intentions, extracting learned mental

commands, assessing the users mental state, e.g. frustration level, being lost, and error behavior, e.g. by the N400 potential. Today, BMIs are mainly used for special medical therapies. However, the research field may gain momentum when the military, gaming, and other industries get involved (van Erp & Werkhoven, 2007; Werkhoven & van Erp, 2007).

The Howard Dean for Iowa Game was the first political campaign game, with the purpose to help Howard Dean supporters to understand grassroots and encourage them to participate in pre-caucus campaigning. The New York Fire Department has used a game designed for training fire fighters on how to deal with conventional, environmental, biological and terror-based incidents, while functioning as a team. There is also an increasing interest in applying computer games to other areas, e.g. military or corporate training and education (Zaphiris & Ang, 2007).

The Rapid Decision Trainer is a virtual and interactive game engine-based simulation developed for the US Army's Infantry Officer Basic Course (IOBC). The *Rapid Decision Trainer* is used for preparation of live-fire exercises. In the simulation each participant can serve as a platoon leader (Pike, Anschuetz, Jones & Wansbury, 2005). An evaluation has been performed by Christ and Beal (2005) with lieutenants as participants. Most participants thought that *the Rapid Decision Trainer* had training value. They also indicated that they were not fully psychologically involved, since the realism portrayed in the simulation was not high, but adequate for training. Christ and Beal (2005) concludes that this challenges the claim that more immersive and realistic simulations are required for effective training, and supports that good training outcomes may be achieved with less resource intensive methods.

America's Army is a serious internet -based multiplayer game directed by US Army Office of Economic Manpower Analysis). It is utilized to train Special Forces Team Leaders (Raybourn, 2007), and for recruitment (e.g. Werkhoven & van Erp, 2007). The purpose is to promote the Adaptive Thinking & Leadership (ATL) Program with augmented experiential training that hones critical thinking, mental agility, interpersonal adaptability, cultural acumen, and observational skills. A preliminary user study showed that the participating officers found themselves engaged with realistic scenarios. They also believed that they learned more about their strengths and weaknesses (Raybourn et al., 2005).

LG-PROTECTOR is a strategic combat gaming tool. It generates intelligent combat strategies, tactics, and courses of action for both friendly and hostile forces and calculates the probability of mission success. The software is based on Linguistic Geometry (LG), a mathematical model to capture the decision-making ideology employed by the world's most advanced chess players. It is developed by the former Soviet Union chess champions Dr. Mikhail Botvinnik and Dr. Boris Stilman. Because LG-PROTECTOR has the ability to solve large complex military and industrial problems, it has been recognized as one of the 25 most important projects developed in the US engineering schools for fighting terrorism. It also has been recognized by DARPA (Defence Advanced Research Projects Agency) for the large-scale RAID (Real-time Adversarial Intelligence and Decision-making) project (Kass et al., 2006; Stilman Advanced Technologies, 2006). The results of a usability study performed by Kass et al. (2006) showed high ratings of efficiency of use, learnability, memorability, and interface design.

The *LG-Expert* is currently developed on the LG-engine. It will be provided with a tool to train military users to "Think like a Commander" (Kass et al., 2006; Stilman Advanced Technologies, 2006).

The Asymmetric Warfare – Virtual Training Technology (AW-VTT) is a research effort to develop a distributed training environment to train soldiers for operations in asymmetric warfare environments. It is developed by the US Army's Research, Development, and Engineering Command, Simulation, and Training Technology Center (RDECOM-STTC), and builds on adaptation of the Massively Multiplayer Persistent (MMP) game engine THERE™, Forterra System Inc. Presently (Mayo et al., 2006), five areas have been modeled: a square kilometer of urban terrain representative of Baghdad, a valley in Afghanistan, a MOUT-style (Military Operations in Urban Terrain) camp set in the Philippines, a suburban California city (for emergency response training), and the New York City harbor. A preliminary evaluation suggest acceptability, considerable potential to meet asymmetric training needs, and optimization of training time. For instance, the participating soldiers thought being able to rehearse within a low-fidelity simulation would enhance the training value of a wide variety of field exercises (Singer & Kusomoto, 2006).

In research on Dynamic Decision Making, simulator games have been used for a long time. One such game is called Newfire. In this game, the participant controls a number of fire trucks and the purpose is to put out forest fires by allocating the fire trucks to various regions of the simulated forest. Newfire and other similar games have proven to be very useful in these research contexts (Løvborg & Brehmer, 1991).

The Department of Man System Interaction (MSI) at the Swedish Defence Research Agency has performed studies to investigate if training in one micro world effect the decision process in another micro world. Initial training was performed in Newfire (Kylesten, manuscript). Transfer of training was studied in LTA (a computer based training facility for training of command and control) at the Swedish Army's Land Warfar Centre. The study showed transfer of training from Newfire to LTA. For instance, compared to a control group, those with previous training in Newfire performed better, and showed different behavior in their decision making processes (Kylesten, 2007).

The Department of Man System Interaction at the Swedish Defence Research Agency has performed a series of studies to investigate if commercial computer games can be used as an alternative to micro-worlds. The studies showed that computer games are a possible alternative, provided the need is met of methods to specify the requirements for game choosing and to evaluate their usefulness. In the first study, *SimCity 3000* was investigated. This has been followed by studies of *Age of Empire, Counter Strike, Delta Force II, Panzer General III*, and *Rouge Spear*. The aim of the final study with *Delta Force III* was three-fold (Kylesten & Söderberg, 2002):

- To test and evaluate the possibilities to use this type of games to study and develop methods to describe, train and evaluate dynamic decision making at the tactical level.
- To study tactical command and control, decision-making, situational awareness, cooperative work and communication within groups
- To test and evaluate the game engine and its environment.

To study these questions three scenarios were implemented. A UN peace keeping operation at the Balkan peninsula. A search and rescue mission at the polar region, in bad wintry weather, for a missing helicopter. A non-combat operation, where a journalist was assigned to take photos at an illegal drug factory in the south of Europe. These studies showed that the same method and questions used during staff- and field exercises, can be used when studying dynamical decision-making in a game based environment. The advantage of control of the situation and extraneous variables in a game-based computer environment was mentioned. The general experiences of using commercial PC-games for training, education and research were positive. However, it was concluded that

commercial computer games are developed for amusement and recreation, and not with the purpose to replace traditional simulation in training and education. This entails that necessary caution and consideration must be taken when commercial computer games are used for training in a defense context (Kylesten & Söderberg, 2002).

2.4 Differences between a game and a serious game

In strictly entertainment games, a number of techniques are often used to stimulate the fun and to skip the not-so-fun stuff. In a serious game, some of these techniques are necessary to have in order to keep up sufficient degree of realism. Some commonly discussed techniques include (from Michael & Chen, 2006):

Randomness is widely used in just about any game. If used for teaching purposes, a game cannot have too much randomness or the learning objectives might be lost.

Time compression: in entertainment games, there is for instance no time lag between when an order is given and when it is executed. Large battles that in real life would take weeks or months are resolved within minutes or hours. In as serious game, time compression cannot be used as much.

Process simplification is also widely used in entertainment games. Many games “help” the player with automatic features not available in real life, such as reloading of ammunition, selecting the appropriate equipment, etc. In a serious game, many automatic features might be removed.

Headache removal: there are no equipment failures in entertainment games. Guns don’t jam and you never get a flat tire. In a serious game, some of these failures might be wanted.

Perfect communication. In the real world communication is rarely perfect. Commands are given through a chain of command, which takes time and might introduce misunderstandings, or at least delays due to needs of verification. Once again, if communication is to be learnt realistically, non-perfect communication should be simulated.

In a serious game, one or more of the techniques above may be violating with the purpose of the training and might therefore be made more realistic, causing the entire game to have less “game feeling”.

2.5 Game engines for serious games

Delta3D is an open source game engine created at the MOVES institute at the Naval Postgraduate School in Monterey, California. It is originally designed for military game-based simulations, but can be used as the underlying architecture for a wide range of game applications. AI (artificial intelligence) capability has been included in version 1.4, e.g. for control of non-player characters and for evaluation performance. Examples of games and simulations with *Delta3D* as underlying architecture are FOPCSIM (Forward Observer PC Simulator) for training of forward observers for artillery; *Cleared Hot!* for training of airborne forward air controllers; SIMEXAM a driving simulator for driving schools created by the Spanish company SIMSPACE™ (Darken, Anderegg & McDowell, 2007).

HiFi Engine is a simulator engine developed at the Department of Man System Interaction (MSI) at the Swedish Defence Research Agency (FOI). *HiFi Engine* is developed based on open source components, which handle different functionalities, e.g. physics, sound and

network communication (Figure 1). *HiFi Engine* is mainly developed for simulations, and a core of functionality adds specific capability to the simulation engine. *HiFi Engine* is an important tool for simulations and has been used in a number of research experiments (Kylesten et al., 2004). For instance, in a motion based Combat Vehicle simulation, with the purpose of studying multimodal presentation of threat information (Carlander, Eriksson & Oskarsson, 2007). And presently, in implementation of a motion based helicopter simulation for research purposes.

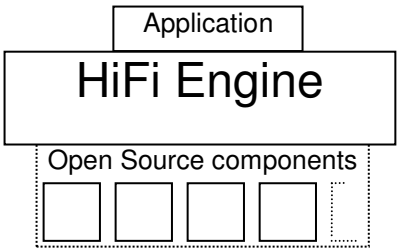

Figure 1. The architecture when a simulation software is developed with HiFi Engine. The application builds on HiFi Engine, which is based on different open source components, which in turn handle different functionalities.

2.6 Examples of utility transfer to reality

Studies performed by Green and Bavelier (2002), and Dye and Bavelier (2004) indicate enhanced visuo-spatial attention in action gamers, both among children and adults. Computer gaming has also been shown to correlate with manual dexterity skills in surgical tasks. A study with surgical residents showed better performance (shorter performance time, fewer errors) for participants with experience of computer games, on a virtual reality based laparoscopic surgery task (Grantcharov, Bardram, Funch-Jensen & Rosenberg, 2003).

2.7 The fidelity plague

Fidelity is the degree of similarity between a game or simulation and the equipment that is being simulated. Fidelity can be represented in two dimensions: the degree to which the simulator looks like (physical fidelity) and acts like (functional fidelity) the real operational equipment that is being simulated (Stanton, 1996).

However, the division of fidelity in two separate concepts is not unproblematic. For instance, realistic radio communication in cockpit with air-traffic controllers (ATC) refers to functional fidelity, whereas equipment for sound generation, amplifiers, loudspeakers etc. refer to physical fidelity. Furthermore, if the sound system presents engine sound, the sound usually refers to physical fidelity (Borgvall, Castor, Nählinder, Oskarsson, & Svensson, 2007).

Stone (2005) discusses the problem of fidelity. He questions if it really matters if the underlying particle physics engine is capable of supporting real-time water spray or dynamic collision effects of barrels rolling down uneven terrain. He also warns that just as the VR community in its early existence was plagued by the proponents of “highest fidelity or nothing,” developers of future game engine-based simulations may face the same temptation. Finally, he puts his hope in Human Factors for *really* making a difference this time around.

Positive transfer is when previous knowledge assists in learning of a new situation, for instance recognizing common concepts or features between different situations. Positive transfer is very effective in transferring previous knowledge or skills to a new situation. Negative transfer counteracts the building of new knowledge and skills. In education positive transfer is often used as a tool to help students expand their knowledge, while teachers actively try to minimize the negative transfer. Taking transfer (positive *and* negative) into account is important when establishing the learning potential in any computer games and training simulator.

In computer games, the physical fidelity is often limited, since most players only have a keyboard and mouse with which to interact with the game. The *Nintendo Wii* offers new ways of interacting with the game, but it is still far from the realism that can be found in for instance airline trainer motion platform simulators.

However, in some cases, a training tool with low fidelity can provide excellent training. A high fidelity simulator might lack the possibility of getting the user involved to such a degree that meaningful training can be attained. The degree of fidelity is often not the most important feature of a simulator. Therefore, it is the human response and perception of the trainer that is of critical importance; not the measureable technical fidelity. (Bell & Waag, 1998; Salas, Bowers & Rhodenizer, 1998; Longridge, Bürki-Cohen, Go & Kendra, 2001).

For educational or training purposes cognitive realism is probably a far more critical factor than fidelity. With this in view, one applicable methodological approach is *Outcome-driven Simulation*. The term was coined by Christopher Riesbeck at Norhwestern University in 1994 (Gordon, 2004). *Outcome-driven Simulation* refers to a class of applications where the user adopts a role in a fictional scenario, and where the decisions and action that the user takes moves the scenario forward in time to new situations that are relevant to the pedagogical objectives. The concept can be viewed as a type of *Goal-Based Scenario*. Computationally, it can be implemented as branching storylines (Gordon, 2004). This methodological approach has been adopted for the development of a computer-based outcome-driven simulator to train digital information skills for small unit leaders of the Army's Future Force Warrior program (Warwick, Archer, Brockett & McDermott, 2005).

3 Definitions

A serious game is a software application developed with game technology and game design principles for a primary purpose other than pure entertainment. A serious game may be a simulation which has the look and feel of a game, but corresponds to non-traditional game events, including business operations and military operations. The games are intended to provide an engaging, self-reinforcing context in which to motivate and educate the players.

Serious games can be classified and divided into to the following subsets:

- *Advergaming* – is the practice of using video games to advertise a product, organization or viewpoint.
- *Edutainment* – is a form of entertainment designed to educate as well as to amuse. Edutainment typically seeks to instruct its audience by embedding lessons in some form of entertainment
- *Games-Based Learning* – refers to games that have defined learning outcomes.
- *Diverted or News Games* – discuss, in a direct way, political or geopolitical problems.
- *Simulations or Simulation Games* – contain a mixture of skill, chance, and strategy to simulate an aspect of reality. Many Serious Games fall into this category.
- *Persuasive Games* – focus on the use of computers to change attitudes and behaviors by presenting and promoting a certain point-of-view or opinion.
- *Organizational-Dynamic Games* – teach and reflect the dynamics of organizations at both individual-, group-, and cultural level.
- *Educational games* – are often intended for an audience of primary or secondary education

3.1 Examples of games that qualify as Serious Games

The following is a list of computer games that often are considered as Serious Games. Since there is no formal definition, the games below should be considered only as examples, and are only valid at the time of the writing of this report (December 2007):

- *America's Army* (Microsoft Windows, Linux, Mac, Xbox, PS2)
- *Close Combat*: First to Fight (Xbox and Microsoft Windows): Began as a USMC training game, converted into a commercial game
- *Dangerous Waters* Developed by a company that makes actual training simulators for navies.
- *Darfur is Dying* (Internet) An online game by mtvU that simulates life in a Darfur refugee camp.
- *DARWARS Ambush!* Convoy Simulator developed as part of DARPA's DARWARS project, designed to create low-cost experiential training systems

- *DoomEd* (Half-Life 2 mod) a single-player first person shooter learning game that combines scientific history with FPS action, exploring bio-terrorism and WWII chemical experimentation.
- *Food Force* (PC) Humanitarian video game. The UN's World Food Programme (WFP) designed this virtual world of food airdrops over crisis zones and trucks struggling up difficult roads under rebel threat with emergency food supplies.
- *Full Spectrum Warrior* (Xbox and Microsoft Windows): Began as a military training game, converted into a commercial game
- *Global Conflict: Palestine* (Mac/Windows): A 3D-adventure/rpg-game. You are given the role of a reporter in Jerusalem, and have to write articles for your paper.
- *Harpoon* (Mac/Windows): Entertainment version was "dual use" from 1989 forward. Professional version Harpoon 3 Professional created in 2002 with help from Australian Defense Department, updated in 2006.
- *Peacemaker* (Mac/PC, $20) is a commercial game simulation of the Israeli-Palestinian conflict designed to promote "dialog and understanding among Israelis, Palestinians and interested people around the world".
- *Re-Mission* (Microsoft Windows): 3-D Shooter to help improve the lives of young persons living with cancer.
- *Tactical Language & Culture Training System* (Microsoft Windows) is a computer-based learning system that let people quickly acquire functional knowledge of foreign languages and cultures. Current titles include Iraqi Arabic, Pashto and French.
- *VBS1* (PC) Based in the Operation Flashpoint game technology, sold as a training tool for the USMC and other military forces around the world.
- *VBS2* (PC) Based in the Bohemia Interactive Australia simulation, VBS1 using the "Real Virtuality Engine 2" developed by Bohemia Interactive and used in Operation Flashpoint: Cold War Crisis in version 1. Related PC game title is Armed Assault.

4 Conclusion

Computer games and video games are often very challenging. They put you, as the player, in front of all sorts of problems, dilemmas, choices you have to make, and challenges you must prevail. The games are neither too difficult, nor too simple. If they where, no one would buy them! Even though they often lack fancy physical fidelity (keeping computer interaction limited to keyboard and mouse), they still manage to keep us working with them for hours.

Whatever the features are that gives computer games such strong motivational forces; it seems it would be very useful to use these features in other training situations, such as military training. The features might be simple such as providing instant feedback of good and not so good moves and choices, or might be more complex such as the working environment, social play, the pedagogies used etc.

Serious games is a fast growing area of software development and it seems to have a very high potential, integrating the well documented positive effects of games and gaming with educational and training aspects applicable to real world settings.

The next step forward is to identify the features /causing the positive effects of games) and to efficiently use them in a real training environment, to allow the positive features of games and gaming to be used in serious training situations.

5 References

Bell, H. H., & Waag, W. L. (1998). Evaluating the effectiveness of flight simulators for training combat skills: A review. *The International Journal of Aviation Psychology,* 8(3), 223-242.

Borgvall, J., Castor, M., Nählinder, S., Oskarsson, P-A., & Svensson, E. (2007). Transfer of Training in Military Aviation. *FOI Methodology report*, FOI-R--2378--SE. FOI: Linköping.

Carlander, O., Eriksson, L., & Oskarsson, P.-A. (2007). Handling uni- and multimodal threat cueing with simultaneous radio calls in a combat vehicle setting. In C. Stephanidis (Ed.), *Proceedings of HCI International 2007 (HCI Part II, HCII 2007, LNCS 4555)* (pp. 293-302). Berlin: Springer-Verlag.

Castor, M., Wallin, N., Nilsson, S-Å, & Moradi, F. (2002). Datorgenererade styrkor – Metoder och möjligheter (FOI-R--0688—SE). Stockholm: Totalförsvarets Forskningsinstitut.

Christ, R. E., & Beal, S. (2005). Evaluation of a game-based trainer for infantry platoon leader decision making, *Proceedings of the Human Factors and Ergonomics Society 49th Annual Meeting, September 26-30, 2005, Orlando, Florida* (pp. 2169-2173). Santa Monica, Ca: Human Factors and Ergonomics Society.

Darken, C., J. (2004). Visibility and Concealment Algorithms for 3D Simulations, *Proceedings of Behavior Representation in Modeling and Simulation (BRIMS) 2004.*

Darken, C., J., Anderegg, B. G., & McDowell, P. L. (2007). Game AI in Delta3D, *Computational Intelligence and Games, 2007. CIG 2007. IEEE Symposium on, Honolulu Hi* (pp. 312-319).

Dye, M. W. G., & Bavelier, D. (2004). Playing video games enhances visual attention in children. *Journal of Vision*, *4*(11):40, 40a, http://journalofvision.org/4/11/40/, doi:10.1167/4.11.40.

Ebner, M., & Holzinger, A. (2007). Successful implementation of user-centered game based learning in higher education: An example from civil engineering. *Computers & Education, 49*, 873-890.

Gordon, A. (2004). Authoring branching storylines for training applications, *Proceedings of the Sixth International Conference of the Learning Sciences* (ICLS-04), Santa Monica CA.

Grantcharov, T. P., Bardram, L., Funch-Jensen, P., & Rosenberg, J. (2003). Impact of hand dominance, gender, and experience with computer games on performance in virtual reality laparoscopy. *Surgical Endoscopy, 17*(7), 1082-1085.

Green, C. S., & Bavelier, D. (2003). Action video game modifies visual selective attention. *Nature, 423*, 534-537.

Hasewinkel, H., & Lindoff, J. (2002). *Modelling, simulation and COTS: Using commercial PC games in command and control studies.* Paper presented at the First-Swedish-American workshop on modeling and simulation, Orlando, FL, Oct. 30-31, 2002.

Kass, S. J., Bjorklund, B., Harrison, D., Castaneda, M., Yakhnis, V., Stilman, B., & Umanskiy, O. (2006). Linguistic geometry: A gaming approach to training combat strategies, *Proceedings of the Human Factors and Ergonomics Society 50th Annual Meeting, San Francisco, Ca* (pp. 2250-2254). Santa Monica, Ca: Human Factors and Ergonomics Society.

Kickmeier-Rust, M. D., Peirce, N., Conlan, O., Schwarz, D., Verpoorten, D., & Albert, D. (2007). Immersive digital games: The interfaces for next-generation e-learning. In C. Stephanidis (Ed.), *Proceedings of HCI International 2007, Beijing (HCI, Part III, HCII 2007, LNCS 4566)* (pp. 647-656). Berlin Heidelberg: Springer-Verlag.

Kylesten, B. (2007). The effect of training in a microworld for decision-making in a command and control training facility, *Presented at the Human Factors and Ergonomics Society Europe Chapter Annual Meeting, October 24 - 26, Braunschweig, Germany*.

Kylesten, B. (manuscript). *Decision processes in a dynamic microworld.* (in preparation for presentation at the Human Factors & Medicine Panel Symposium on Adaptability in Coalition Teamwork, Copenhagen, 21-23 April 2008).

Kylesten, B., Lindoff, J., Hasewinkel, H., Andersson, P., Carlander, O., Fors, K., Hedström, J., Kindström, M., Lindahl, B., & Lif, P. (2004). *Kognitiv lägespresentation* (FOI-R--1436--SE). Linköping: Totalförsvarets Forskningsinstitut.

Kylesten, B., & Söderberg, H. (2002). Lessons learned from using commercial multi-player games in tactical command and control training, *Proceedings of the 13 international training and education conference ITEC in Lille, Apr. 9-11, 2002* (pp. 103-112).

Longridge, T., Bürki-Cohen, J., Go, T. H., & Kendra, A. J. (2001). Simulator Fidelity Considerations for Training and Evaluation of Today's Airline Pilots. Paper presented at the 11th International Symposium on Aviation Psychology, Columbus, OH.

Lundin, M., Castor, M., Holmström Strehlenert, H., Alfredson, J., & Lundin, S. (2005). Beteende- och kognitiv modellering inom NBF-orienterad MoS. In A. W. Berggren (Ed.), *Människan i NBF. Med särskilt fokus på internationella insatser* (pp. 303-341). Stockholm: Försvarshögskolan. (även publicerat som FOI Memo 1563).

Løvborg, L. & Brehmer, B. (1991). *NEWFIRE – A flexible system for running simulated fire fighting experiments*. Risø National Laboratory, Denmark, Risø-M-2953

Mayo, M., Singer, M. J., & Kusumoto, L. (2006). Massively multi-player (MMP) environments for asymmetric warfare. *JDMS, 3*(3), 155-166.

Michael, D., & Chen, S. (2006). *Serious Games – games that educate train, and inform.*. Thomson Course Technology: Boston, MA, USA.

Nählinder, S. (2004). *ACES - Air combat evaluation system* (FOI-R--1368--SE). Linköping: Swedish Defence Research Agency.

NATO RTO HFM128 (forthcoming 2008). Human Behavior Representation in Constructive Simulation. NATO RTO Technical Report.

Nilsson, S.-Å., Allberg, H., Lundin, M., Wallin, N., & Castor, M. (2004). *Datorgenererade styrkor med mänskligt beteende - CGF-verksamhet vid FOI 2004* (FOI-R-1489-SE). Stockholm: Totalförsvarets Forskningsinstitut.

Pew, R. W. & Mavor, A. S., Eds. (1998). *Modeling Human and Organizational Behavior Application to Military Simulations*. National Academy Press, Washington, D.C.

Pike, W. Y., Anschuetz, R., Jones, C., & Wansbury, T. (2005). The Rapid Decision Trainer: Lessons learned during an R & D development and fielding process, *Proceedings of the Interservice/Industry Training, Simulation & Education Conference (I/ITSEC)*.

Raybourn, E. M. (2007). Applying simulation experience design methods to creating serious game-based adaptive training systems. *Interacting with Computers, 19*, 206-214.

Raybourn, E. M., Mendini, D. K., & Heneghan, J., 2005. Adaptive thinking & leadership simulation game training for special forces officers. *I/ITSEC 2005 Proceedings, Interservice/ Industry Training, Simulation and Education Conference Proceedings, November 28–December 1, Orlando, FL, USA*.

Salas, E., Bowers, C. A., & Rhodenizer, L. (1998). It Is Not How Much You Have but How You Use It: Toward a Rational Use of Simulation to Support Aviation Training. *International Journal of Aviation Psychology, 8(3)*, 197-208.

Singer, M. J., & Kusumoto, L. (2006). Developmental evaluation of a distributed online simulator, *Proceedings of the Human Factors and Ergonomics Society 50th Annual Meeting, San Francisco, Ca* (pp. 2699-2672). Santa Monica, Ca: Human Factors and Ergonomics Society.

Stanton, N. (1996). Simulators: a review of research and practice. In N. Stanton (Ed.), *Human factors in nuclear safety* (pp. 117-140). London: Taylor & Frances.

Stilman Advanced Strategies (2006*). Linguistic Geometry Tools: LG-PACKAGE*, 50 pp, with 8 demos on DVD (also available at http://www.stilman-strategies.com/movies/LG-PACKAGE.pdf). Retrieved November 7, 2007.

Stone, R. J. (2005). The convergence of computer games and virtual reality, *Proceedings of HCI International, Las Vegas, 22-27 July, 2005*.

van Erp, J. B. F., & Werkhoven, P. J. (2007). Brain machine interfaces for serious gaming applications. In C. Stephanidis (Ed.), *Proceedings of HCI International 2007, Beijing*. Berlin Heidelberg: Springer-Verlag.

Wallin, N., Lundin, M., Nilsson, S.-Å., & Hasewinkel, H. (2003). *Datorgenererade styrkor med mänskliga egenskaper* (FOI-R-1076-SE). Stockholm: Totalförsvarets Forskningsinstitut.

Wallin, N., Nilsson, S.-Å., Lundin, M., & Castor, M. (2005). *Guidelines för utveckling och användning av modeller för mänskligt beteende* (FOI-R-1837-SE). Stockholm: Totalförsvarets Forskningsinstitut.

Warwick, W., Archer, R., Brockett, A., & McDermott, P. (2005). Simulation based training for the future force warrior, *Proceedings of the Human Factors and Ergonomics Society 49th Annual Meeting, September 26-30, 2005, Orlando, Florida* (pp. 2179-2182). Santa Monica, Ca: Human Factors and Ergonomics Society.

Weil, S. A., Hussain, T., Brunyé, T., Sidman, J., & Spahr, L. (2005). The use of massive multi-player gaming technology for military training: A preliminary evaluation, *Proceedings of the Human Factors and Ergonomics Society 49th Annual Meeting, September 26-30, 2005, Orlando, Florida* (pp. 1186-1190). Santa Monica, Ca: Human Factors and Ergonomics Society.

Werkhoven, P. J., & van Erp, J. B. F. (2007). *Serious gaming requires serious interfaces.* Paper presented at the Brain-Computer Interfaces and Games, Workshop at ACE (Advances in Computer Entertainment) 2007, Salzburg.

Zaphiris, P., & Ang, C. S. (2007). HCI issues in computer games. *Interacting with Computers, 19*, 135-139.